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RESEARCH ON EDIBLE FOREST INSECTSAND PROPOSE SOLUTIONS TO CONSERVE THEM IN THE NORTHWEST REGION OF VIETNAM

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INTRODUCTION

1. Reason for choosing the topic

Edible insects have been well known and exploited for thousands of years. According to the Food and Agriculture Organization (FAO), in order to meet the food demand of about nine billion people on the globe by 2050, insects play an important role because the world currently has about 2,000 species of edible insects (Durst *et al*., 2010).

Agricultural production is the main economic activity of most ethnic minorities in Northwest Vietnam. Their lives are facing extremely difficulties with high rate of poor households compared to other regions in the country (24% in 2009) (Soils and Fertilizers Research Institute, 2014). Therefore, forest insect resources are associated with the formation and development of economy and culture of more than 20 ethnic communities in this area. Ethnic groups in the Northwest have used many edible insects such as *Omphisa fuscidentalis*, *Brihaspa atrostigmella*, *Tessaratoma papillosa* etc. In particular, bamboo borer is favored as it is a delicious, nutritious, and healthy food. However, quantity of edible insects in general and bamboo borer in particular is not enough to meet the needs of local people.

Globally, research and exploitation of edible insects have made a large number of achievements. However, in Vietnam, especially in Northwest region, research in this field isstill limited. Exploitation methodology and the use of insects are also spontaneous. Many insects have not yet been properly valued and have only been harvested from the wild in an unscientific way. Insect products have been consumed locally, have not been developed into commodity-producing foods. Lacking of awareness and arbitrary exploitation are causing the decline of many species and posing the risk to extinction. In order to conserve and rationally exploit this resource in the area and to help local communities develop sustainable socio-economic conditions, it is essential to carry out the research project "***Research on edible forest insectsand propose solutions to conserve them in the Northwest region, Vietnam***".

2. Research objectives

***General objectives*:** Survey on the status of edible forest insects; Study on morphology, biology and nutritional values of bamboo borer (*Omphisafuscidentalis* Hampson) as a scientific basis to propose solutions for the exploitation, development and sustainable management of forest insect resources in the Northwest region, Vietnam.

***Specific objectives*:** (1) Identification of thecomposition of forest edible insect speciesin Northwest region; (2) Identification of morphological characteristics, biology and nutritional values of bambooborer(*Omphisa fuscidentalis* Hampson); (3) Propose solutions to conserve and develop edible forest insect species in general and bamboo borerin particular in the Northwest of Vietnam.

3. Research subjects and scope

(1) Research subjects: Potential edible forest insects; (2) Research scope: Interview survey was conducted at three provinces with typical characteristics and ethnic groups such as Thai, H'mong, Muong, Dao for the Northwest region region such as Son La, Dien Bien and Lai Chau. Fieldwork was carried out in Son La province, representing the study area.

4. Scientific and practical significance

- The thesis provides scientific basis for conservation of insect species, including information on species composition, check-list of important edible forest insects and their biology and ecology in the Northwest region of Viet Nam.

- The thesis also provides solutions for the development of edible forest insects in the Northwest region of Viet Nam, particularly the rearing techniques of bamboo borer were developed throughout the study.

5. New contribution of the thesis

(1) The thesis develops, for the first time, a systematic check-list of edible forest insects and provide information on the indigenous knowledge related to the exploitation and use of edible insects in the Northwest of Viet Nam. (2) Moreover, this thesis also provide information on morphology,

biology and nutritional data of the bamboo borer, (*Omphisa fuscidentalis* Hampson) in the study area.

Chapter 1: LITERATURE REVIEW

Based on a review of 118 papers published by domestic and international authors on food insect, the topic covered the main contents for studying edible forest insects and proposing solutions to conserve them in the Northwest of Vietnam. Since then, there have been some general points and situations as the basis for identifying what needs to be done.

- Research on composition of edible forest insects: Edible forest insectsis an interesting topic in many nations across the globe as they are considered as an important food source in the future for scientists to research and apply.

- Research on types of edible forest insects: The consumption of forest insects is quite common in some countries at a large number of types and species. In reality, number of species can be used as food could be much higher than listed species.

- Study on life cycle worksheet of edible insects: Insects usually appear in a large quantity in a short time. They are not all year around and unpredictable.

- Research on indigenous knowledge in pre-processing and processing of insects: Insects used as food are new with limited research available. However, knowledge of how to use edible insects is very common in indigenous tribes. Different countries have different ways of pre-processing and processing to create their own unique flavor.

- Research on nutritional value of insect: edible insects are rich in protein, amino acids, fatty acids, vitamins and carbohydrates. Especially, the insect' body also has essential amino acid.

- Research on food market of insect: Edible insectsare sold in the market, generating income for people including bamboo borer.

- Research on conservation and breeding: Over-exploitation for economic and social purposes is extremely dangerous. There is a potential risk that many insect species will be depleted, being threatened to extinction. Therefore, the research on conservation and breeding solutions is necessary. Several countries are implementing researches and breeding edible insects source for humans.

- Habitat of bamboo borer (*Omphisa fuscidentalis* Hampson): Bamboo borer is a tropical insect species, widely distributed throughout Asia. It's a common species in Thailand, also found in Laos, China and Myanmar. According to research results of several authors, although there are a large number of bamboo tree species, but bamboo boreronly occurs in certain species of bamboo.

Topic of edible insectshas been quite well studied with some great achievements in the world. But in Vietnam, research on insects is limited. So far, there is no such comprehensiveinformation on the insect as food in Vietnam in general and in the Northwest region region in particular. Especially, for bamboo borer, the world has recognized its great economic value and promoted the development of this species as a source of income for localpeople. However, in Vietnam, there is no scientific document mentioned about this species.

Chapter 2: RESEARCH LOCATION, TIME, MATERIAL, CONTENT AND METHODOLOGY

2.1. Location and time

Research location: In the Northwest Region of Vietnam (Interview survey was conducted at three provinces with typical characteristics and ethnic groups such as Thai, H'mong, Muong, Dao for the Northwest region region such as Son La, Dien Bien and Lai Chau. Fieldwork was carried out in Son La province, representing the study area).

Study period: 4 years, from December 2012 to December 2016

2.2. Research materials and tools

Research material: host plant to breedbambooborer: Hamilton's bamboo (*Dendrocalamus hamiltonii* Nees & Arn) and *Dendrocalamus sericeus* Munro.

Research tools: cage for breeding bamboo borer, bamboo stemseparated from tree, bamboo base, pot ...

2.3. Research content

1. Baseline survey of edible forest insects in the Northwest region. (1.1) Investigation of composition of edible insect speciesin the Northwest region; (1.2) Survey on the distribution characteristics of edible insects in the study area; (1.3) Systematize indigenous knowledge related to the exploitation of edible insectsof the local people in the Northwest region.

2. Study the basic characteristics of bamboo borer. (2.1) Morphological characteristics of bamboo borer; (2.2) Biological characteristics of bamboo borer: mating, egg laying, life cycle, growth and development; (2.3) Nutritional value of the larvae of bambooborer (chemical composition, composition and content of amino acids, fatty acids)

3. Propose solutions to conserve and develop edible insects in the Northwest region. (3.1) Propose solutions for conservation and general development of edible insects; (3.2) Propose management and development solution for bamboo borer.

2.4. Research method

2.4.1. Inheritance method

(1) Collect, analyze, and synthesize documents related to the characteristics of the study area. (2) Collect, analyze, and synthesize domestic and foreign scientific and technical documents in the field of edible insects. All related document published in last 20 years will be collected.

2.4.2. Key method of surveying edible forest insects in the Northwest region region

2.4.2.1. Interview method: Using semi-structured interview method to collect information on the exploitation and use of edible insects of the ethnic groups of Thai, H'mong, Muong and Dao. 120 interviewees of village chairman and the elderly (40 people/site in 3 locations: Dien Bien, Lai Chau and Son La) who has much experience and knowledge will be conducted. During interview, questionnaires with images attached or insects specimens will be used (Appendix 1).

*2.4.2.2. Field survey method:*Field transects with standard points where information on composition of species, catch rate, exploitation ability, usage situation and species distribution characteristic, etc. will be collected. The total length of transects is 115 km with 16 routes has been mapped (Figure 2.1), belongs to the administrative boundaries of 8 districts of Son La province (Table 2.1). On transect route, whenever the habitat changes, a standard point will be placed. Of 16 routes, 220 points were created (Table 2.2). Particularly, some caterpillars, banana leaf rollers and litchi stink bugs only occur in certain habitats. Therefore, besidessurvey pointsestablished following above method, additional random points on the same habitat types was added to meet the condition that each insect species has the total number of survey sites greater than or equal to 30 points. To collect information on the experience of exploitation and processing of insects, we conducted census surveys, talk with local people at the market or at their home.

2.4.2.3. Treatment of insect specimens: Specimens can be treated in two basic ways: Immersion and Drying.

2.4.3. Research the basic characteristicsof **Bamboo borer**

2.4.3.1. Field survey: Conducted four transect routes at four districts (Thuan Chau, Song Ma, Yen Chau, Moc Chau) in Son La province with a total route length of 31 km. On the survey routes, randomly selected 100 bamboo clumps (equally distributed on each route) with each of the different bamboo species (*Dendrocalamus membranaceus*; *Dendrocalamus hamiltonii* and*Dendrocalamus aff. Pachystachys*) to investigate in detail. This field survey was conducted to collect more information on the distribution, morphology, and biology of bamboo borer combined with collecting bamboo borer to breed.

(1) Survey of bamboo borer in bamboo clump: Trees with bored internodes were cut down for detailed investigation. At each intenodes, count number of individuals according to their development stages; (2) Larva survey: Field surveys were conducted periodically every 5 days for further information

on instar classification of bamboo borer from 20 August 2015 to 10 October 2014. Find the damaged bamboo shoots then chop them to catch the larvae. Measure the larva's capsule width, body length, and morphological description ... of 132 larvae.

2.4.3.2. Rearing method of bamboo borer

Larva source: The larvae were collected in the wild from late October to April next year. Pupae werecollected in June and July each year; Host plants for rearing the larvae were *Dendrocalamus hamiltonii* and *Dendrocalamus membranaceus*; Tools for breeding include cages, directly breed in bamboo stemseparated from trees, breed in bamboo tree planted in pot or planted in gardens.

+ Rearing in bamboo stems: Each bamboo stem held about 30 larvae. At one end of the stem, it was covered with dried banana leaves or sticky tape. Bamboo stem was changed every 10 days. This method was only a supportive method for rearing larvaein bamboo trees, in cages and for monitoring the development of the larvae in time.

+ Rearing in bamboo tree planted in pot or in gardens: This was similar to grow in the bamboo stem, but the bamboo tree's top wascut, planted and cared in pot and watered regularly to keep it fresh. Drill a hole (about 2 cm in diameter) in the middle of internode, and put the larvae through that hole. Periodically check once a month.

+ Rearing cages: The cage is 2m long, 3m wide and 2m high. Bamboo cages were built in bamboo gardens, covering bamboo shoots. The pupae werecollected from the wild and placed in bamboo tube hanging upside down in the cage. Monitor the emergence, mating and laying eggs.

2.4.3.3. Analytical method of nutritional value of bamboo borer

The research material is the larvae which has reached the 5^{th} instar, collected from natural bamboo forest in Son La province. Total protein content determination method was applied in accordance with TCVN 8128:2009; Lipid content according to TCVN 8136:2009; Calcium content according to TCVN 1526-1:2007; The potassium and magnesium content in accordance with TCVN

1537:2007; Zinc content according to JAS-SOP-45; The composition and content of amino acids present in bamboo borer was determined by HPLC-H.H.QT.046 test method; The fatty acid content found in bamboo borer is determined by PN.1H041 test method; Analysis of nutrient content of bamboo borerwas conducted at the National Center for Food Analysis and Assessment, Food Industries Research Institute, Hanoi.

2.4.4. The methodology of research to propose solutions to conserve and develop edible insect species in the Northwest region, Vietnam

From results of interviews and surveys, field surveys, data collection, analysis and classification of threats to insect resources as food in the study area, we proposed solutions to conserve and develop edible insect species in general and bamboo borer in particular.

2.4.5. Data analysis

- Synthesize the collected data to make a check-list the insect species which has food value.
- Data are processed and analyzed with common forestry statistical functions in Excel 2007.
- To estimate the observed ratio of insects (P%), using the formula:

$$P\,\% = \frac{n}{N} \qquad (1)$$

Meanwhile:

P%: The observed ratio of one specific insect species (% of tree with caterpillar)

n: Number of survey dots with specific insects (number of surveyed trees with caterpillar)

N: Total of points (total of surveyed trees)

Based on the value of the observed rate, classify as follow: common species has a value P% > 50%; less common species are 25% ≤ P% ≤ 50% and rare species with P% < 25%.

- Determine the density of Bamboo borer :

$$M_s = \frac{\sum_{i=1}^{n} S_i}{n} \qquad (2)$$

Meanwhile: M_S = Density of bamboo borer(larva or pupa/tree)

S_i = Total of bamboo borer of the ith tree

n = Total of surveyed trees

- Examining the difference in clump with caterpillar and number tree with caterpillar among bamboo species: Using U-test to compare two independent samples (Nguyen Hai Tuat and Ngo Kim Khoi, 2009).

$$U = \frac{p_1 - p_2}{\sqrt{\frac{p_1(1-p_1)}{n_1} + \frac{p_2\ (1-p_2)}{n_2}}} \qquad (3)$$

Meanwhile: p_1, p_2: Ratio of clump or tree with caterpillar of bamboo species number 1 and 2

n_1, n_2: Total of number surveyed clumps and trees of bamboo species number 1 and 2

If the absolute value of $U > U_{\alpha/2}$ ($\alpha = 0.05$ then $U_{\alpha/2}$ = 1,96) so the hypothesis is rejected. So there is difference in clump with caterpillar and number tree with caterpillar among bamboo species.

Chapter 3: RESULT &DISCUSSION

3.1. Basic characteristics of edible forest insects in the Northwest region of Vietnam

3.1.1. The compositionof edible insects in the Northwest region

There were 34 species belongs to 31 insect genus of 21 families, 9 orders have been used as food in the Northwest region. Particularly, for species *Macrotermes sp.* species name remainsunidentified. There were 5dominant orders of insects, including Hymenoptera (8 species, 23.5%), Orthoptera (7 species, 20.6%), Coleoptera (5 species, 24.7%); Lepidoptera and Hemiptera (4 species, 11.8%). The number species of these five orders were accounting for 82.4% the edible insect speciesin the Northwest region of Vietnam. The other orders had very few species, only 1 to 2 species, accounting 2.9 to 5.9%. The insect species as food in general and forest edible insects in the Northwest region in particular were not fully and accurately identified and listed. In fact, the number of species is much higher. There were 33 out of 34 species of insects were used in all three provinces of Son La, Dien Bien and Lai Chau. Particularly, banana leaf rolled worm is used only in Yen Chau, Son La. Thus, there was no significant difference in the insect species composition used for food between the three provinces, especially forest insects. There wasa difference among provinces inthe level of using certain species as food. For example, bamboo borerwasfavoredin Son La while *Brihaspa atrostigmella* is used more in Dien Bien. Insects were used as food in most growth stages. 28/34 insects species were used at larva stage, accounting for 82.4%, followed by adults stage with 25/34 species, accounting for 73.5%, the least used, pupa stage, was only 10/34 species, accounting for 29.4%. Many species of insects were also used in two or three stages of life cycle. Some insects also produced other commercial products such as honey, beeswax, pollen, etc. There were 3/34 species for these products, accounting for 8.8%.

Of the 34 insects species used for food in the Northwest region, there were groups of pests such as: *Atractomorpha sinensis, Oxya chinensis, Tarbinskiellus portentosus, Apriona...*; Natural predator: *Crocothemis servilia, Hierodula patellifera, Crematogaster travanconresis*, *Oecophylla smaragdina...*; Insects of high conservation value such as *Lethocerus indicus* and specialty insect groups: *Apis cerana, Apis florea, Philosamia cynthia* ...Similarly, forest insects in the Northwest region are also divided into 3 groups, 8 Pests: *Macrotermes sp.*, *Cryptotympana atrata, Meimuna mongolica, Holotrichia sauteri, Cyrtotrachelus buqueti, Cyrtotrachelus longimanus, Brihaspa atrostigmella* and *Omphisa fuscidentalis;* Natural predator (*Discolia vittifronts*) and specialty insects (*Apis dorsata*) have only one species. With pests group, it should be promoted to use these edible insects while natural predator, specialties or conservation value group, besides using for food, protection and development measures must be taken.

3.1.2. Distribution characteristics of edible insects in the study area

3.1.2.1. Observation rate of edible insect species

Out of 34 species, 9 species are common (3 species of forest insects), 12 species are rare (5 species of forest insects) and 13 species are extremely rare (2 species of forest insects). These numbers are consistent with the majority (> 50%) of the statements made by local people during interview. The common forest insect species are *Meimuna mongolica, Cryptotympana atrata, Holotrichia sauteri;* less common species include *Macrotermes sp*., *Cyrtotrachelus buqueti, Cyrtotrachelus longimanus, Omphisa fuscidentalis* and *Brihaspa atrostigmella*; extremely rare species are *Apis dorsata* and *Discolia vittifronts*. Most of the rare and extremely rare species are very agile, such as *Apis dorsata* and *Discolia vittifronts*... or have very few individuals such as *Hierodula patellifera, Tenodera sinensis*...; some plant-eating species are less common because their host plants are small and uneven, depending on the forest habitats such as *Omphisa fuscidentalis* and *Brihaspa atrostigmella* etc. Particularly, *Erionota torus* which is used locally in some localities in Yen Chau district, Son La province by the Sinhmun ethnic group. Thus, interviewees from outside of Yen Chau did not mentioned about it during interview. *Lethocerus indicus* usually lives in lakes, ponds, lagoons or wet rice fields, but nowadays, due to the overuse of pesticides and chemical fertilizers in agriculture and forestry, this species becomes very rare throughout its historical distribution range.

3.1.2.2. Distribution characteristic of edible insects

Of 34 insect species used for food in the Northwest region, 10 species are often seen in forest habitats; 9 species are more common in agricultural habitats; 3 species are found in aquatic habitats. The remaining species are found in both agriculture and forestry ecosystems. However, in the Northwest region, these species are more likely to be found in forest habitat due to large proportion of forest and hilly land planned for forestry development compared to other types of land use, i.e. agricultural land and other land. Although edible insects are quite diverse and rich, but they are not available all year around. They are often seen in late spring to early fall, from March to September. Particularly, larvae of *Brihaspa atrostigmella* and *Omphisa fuscidentalis* appear and exploitable from September of the previous year to March and April of the following year. Most of insect species appear and being harvestable from May to July. In May, there are 21/34 species; June has 24/34 species and July has 23/34 species. There is almost no insect often appears in large quantity in wild.

3.1.2.3. Exploitation ability ofedible insects

Out of 34 species of edible insects in the Northwest region, 9 species are highly exploitable, 13 are medium exploitable and 12 species are low exploitable. Of which, six forest species are medium exploitable, including *Macrotermes sp*., *Discolia vittifronts, Brihaspa atrostigmella*, *Omphisa fuscidentalis*, *Apis dorsata* and *Cryptotympana atrata*; 2 species for low exploitable are *Cyrtotrachelus longimanus, Cyrtotrachelus buqueti*; two species that are most likely to be exploited are *Meimuna mongolica* and *Holotrichia sauteri*. Just like most of edible insects in the Northwest region, species that are most exploitable are common. Particularly, *Cryptotympana atrata* is a common species, but exploitation ability is medium because a small number but easily located via its calls. With *Gryllus testaceus*, an agro-forest insect, although the observation rate is low but has high exploitable ability as this *Gryllus testaceus* has a large number of individuals but difficult to detect during the day time. With *Omphisa fuscidentalis* and *Brihaspa atrostigmella*...eat only a certain kind of food, and live only on certain host plant trees in bamboo forest. *Dendrocalamus hamiltonii*, *Dendrocalamus sericeus*, and *Dendrocalamus aff. Pachystachys* are listed as host plant for bamboo, and *Thysanolaena latifolia* for *Brihaspa atrostigmella*. Meanwhile, the host plant is often fragmented. Therefore, the ability to accumulate and develop these species populations is limited. Overall, the exploitation of edible insects in general and edible forest insects in particular in the Northwest is spontaneous, lacking of conservation planning and sustainable exploitation.

3.1.2.4. Edible insects factsheet

Of the 34 species recorded, 27 species are commonly used, accounting for 79.4% (10/10 species of forest insects, accounting for 100% of species in the group); There are only 7 species rarely used, accounting for 20.6%, including: *Tenodera sinensis, Hierodula patellifera, Halyomorpha picus, Lethocerus indicus*, *Dytiscus marginalis, Erionota torus* and *Apriona germari*. According to the local people knowledge, seven insects are rarely used because the *Tenodera sinensis, Hierodula patellifera* and *Halyomorpha picus* are often used as ingredient for tradition medicine. Thus, you only catch these insects for curing disease purposes. *Lethocerus indicus*, *Dytiscus marginalis* and *Apriona germari* are rare species, hard to collect. Consequently, there is not many to use regularly even in the larval season. *Erionota torus* is not the favorite food of many ethnic groups, so few people mention this species when interviewed.

Tenodera sinensis, Hierodula patellifera, Crematogaster travanconreis and *Oecophylla smaragdina* are natural predators. They are very useful insects for human production, should limit the exploitation; Bees have a narrow distribution, especially bees with honey, that pollinate the crop, also should limit the exploitation; *Philosamia cynthia* has been used quite commonly. This is the only insect that is tamed by humans for silk and for food. They are widely bred and farmed in local households. At present, the farming of crickets has appeared in many localities, generating economic value. Therefore, coupled with the exploitation in the wild, we also need to learn the techniques and practice breeding to ensure the sustainable exploitation of edible insect resources. *Lethocerus indicus* are aquatic insects, not only a nutritional and pharmacological significance, but also an aquatic live indicators, which help to kill parasites those transmitted disease. However, the number of *Lethocerus indicus* emains extremely low throughout its historical distribution range. Thus, *Lethocerus indicus*should be bred, conserved, and developed to better serve human's needs, especially in food source.

3.1.2.5. Market information of edible insects

Of the 34 species of edible insects, there are 20 species, accounting for 58.8% (8/10 forest insect species, accounting for 80% of species in the group) not only use in local household but also sell easily at local markets. Market price of *Omphisa fuscidentalis, Brihaspa atrostigmella, Discolia vittifronts, Vespa affinis* and *Apis dorsata* are stable while price of others fluctuate seasonally. At the beginning and end of harvest season, insect is scarce, the price is often higher than in the middle of the harvest season. The highest price is paid for *Vespa affinis* and *Discolia vittifronts*, 350,000 VND/kg. Sale price of insects in Northwest region is not much difference compared to other regions in the country. In general, the exploitation of edible insects is spontaneous and the trade is operating at small scale. There is no official, registered food insect trading organization operating as in Taiwan, France, Germany, etc...

3.1.3. Using indigenous knowledge of edible insects in the Northwest region

3.1.3.1. Indigenous knowledge of insect exploitation

There are 5 ethnic groups with the experience, knowledge to choose the season, tools and methods of catching edible insects. For each edible insect, people in the Northwest region have gathered a variety of capture experiences for high efficiency and safety such as hand catches, lights, fire, racquets, forest quake…. However, the exploitation is rudimentary and lack of technology, some destructive measures such as burning bees nest to collect honey.

3.1.3.2. Indigenous knowledge in the food preparation from edible insects

Before pre-processing into food, insects in general and forest insects in particular are processed differently, depending on their characteristics. Option 1: Some species need to clean up, pick up impurities before processing such as: ant eggs, larval and pupae of bees; Option 2: There are some species that need to be cleaned with warm water, hot water or diluted saltwater such as *Halyomorpha picus, Nezara viridula, Lethocerus indicus, Crocothemis servilia, Macrotermes sp*., *Dytiscus marginalis, Brihaspa atrostigmella*, *Omphisa fuscidentalis, Erionota torus,…*; Option 3: Cut off wings and legs and rinse with hot water before processing with adult insects of *Meimuna mongolica, Cryptotympana* *atrata, Apriona germari*, *Cyrtotrachelus longimanus, Cyrtotrachelus buqueti,…*; Option 4: Some species need to be processed more carefully, as remove wings, legs, antennae and gut and then wash with hot water then drain on water before processing such as *Oxya chinensis, Euconocephalus broughtoni, Euconocephalus incertus, Atractomorpha sinensis, Hierodula patellifera, Tenodera sinensis,…*

3.1.3.3. Indigenous knowledge about the processing edible insects

Dry roasting is the most common processing method applied for insects. Specifically, insects are put into a pan with sour bamboo shoots wateror softenedsour bamboo shoots, stir well to dry, then add a little bit of oil, salt, glutamate. Keep stirringuntil it turns to ripe yellow colour and be ready to serve on dish. If there is no sour bamboo shoots water, heat the oil well, then drop the insect into the pan, stir well until it turns to ripe yellow. Add sauce, salt, glutamate, chopped chili, minced lemongrass or well-chopped lemon leaves. In addition to above roasted dish, other dishes such as: wild betel (*Piper sarmentosum*) dragonfly soup, deep fried stuffed crickets, ant's egg soup, steamed bee pupae, ... It can be seen that indigenous knowledge about the processing of food from insects in any nation is extremely rich and diverse, meets food safety requirement with the purpose of creating delicious and attractive dishes for the enjoyment.

3.2. Basic features of Bamboo borer

3.2.1. Morphological characteristics

Bamboo borer was described by Hampson in 1896 as *Omphisa fuscidentalis*. However, prior to this, Hampson also gave this species another synonym as *Chilofuscidentalis*, in Lepidoptera order, Crambidae family. It is known as *Tômẹ* in Thai, *Kabxyoobyas* in Mong;*Háokanh*in Dao, and *Đôicle* in Muong.

3.2.1.1. Egg morphology

Bamboo borer's eggs are often laid in a cluster in a newly developed bamboo shoot. Eggs are very small, and elongated. The newly laid eggs are often green-white colour with smooth shell, flat and stack together like fish scales. One day after, the egg turns to light brown colour. This study's result on egg morphology of Bamboo borer is consistent with Kayikananta (2000), Bamboo borer's eggs are very small, with a diameter of approx. 1.4mm, are stacked up in an area of 0.7 x 0.7; 1 x 1, or 1 x 2 cm.

3.2.1.2. Morphology of the larvae

The head's width of the larva will be a reliable parameter to estimate the Bamboo borer age. Based on the measurements of the larva head's width, their frequencies could be grouped into 5 distinct groups with each group corresponding to one instar. The head's width of the larvae varies greatly from 0.492 to 2.892mm and is grouped into five different instars. Instar 1 from 0.492 to 0.692 mm, instar 2 from 0.692 to 0.992mm, instar 3 from 0.992 to 1.492mm, instar 4 from 1.492 to 2.192mm and instar 5 from 2.192 to 2.864mm. At different instars, Bamboo borer's larva also has different color and body length.

The larva stage has five instars (before entering the compulsory mating period) with different colors and sizes. Instar 1larva has an orange-brown head and a very well developed lower jaw while its body is dark brown, with black stripes running in the middle of the back. Larva body also hasvery long white hairs scattered at instar 1. Body length: 2 - 4 mm (average 2.8 ± 0.10 mm); Instar 2 larva has more color variation than instar 1 ones with the body turns to light yellow, with dark brown stripes running in the middle of the back. On the body, there are some long yellow-white hairs scattered. Body length 10-17 mm (average 14.6 ± 0.38 mm); At the instar 3, the larva gradually turn into ivory white with stripes of light brown colour running along the middle of the back, On the body, there are short brown yellow hairs scattered. Body length 17-24 mm (average 22.1 ± 0.28 mm);Instart 4 larva experiences a little change in colour in comparision with instar 3ones. Body length 25 - 33 mm (mean 29.0 ± 0.50 mm); Entire body of instar 5larva are milky, with small, short, reddish-brown hairs scattered. The oldest larva, i.e. at instar 5, was 35-40 mm in length (average 36.9 ± 0.31 mm).

Bamboo borer's larvae are multi-legged worms. Each head's side has 5 ocelli (simple eyes) nearby the antenna. The prothorax's back is yellowish-brown, shiny and hard. Larva has nine pairs of spiracles, one pair in the prothorax segment, and eight pairs in the abdomen, from $1^{st}$to 8^{th} segment.

3.2.1.3. Morphology of the pupa

Bamboo borer's pupae have an object pupal form. At early pupal stage, the pupa's belly is milky white; while its head, thorax, and wing are light green. After a few hours, the whole body turns reddish brown. The pupa is 30-40 mm (mean 35.3 ± 0.50 mm) in length, 4 - 6mm (average 4.99 ± 0.01 mm) in width. Pupal weight is about 0.3 grams and female is often larger than male. The pupae have 10 abdominal segments, and nine pairs of spiracles located in the same position as the larva. The feminine pupa's anal segment is often rounded while the males one is pointier.

3.2.1.4. Morphology of the Adult

Adult bamboo borer has a dark brown body, yellowish-brown wings, with dark brown patterns running in a zigzag-lined on the edge of the wing. The outer edge of the fore and hind wings are covered by black-flagged hairs. There are many smooth bright brown hairs covering the ovipositor. Antennae are thread-like shaped, place along the back when perching. Basically, mature males and males are similar in shape, and colour. Males are often smaller than females. Males have slender belly, females have bulging belly. The male body length is 18 - 20mm (average 19.1 ± 0.11 mm), females are 21 - 23 mm (mean 22.0 ± 0.10 mm) in length. The wingspan of the males is 37 - 39 mm (average 37.9 ± 0.09 mm), females' wingspan is 40 - 42 mm (average 40.9 ± 0.11 mm).

3.2.2. Biological feature of bamboo borer

3.2.2.1. Biological feature of larva stage

The larval stage of bamboo boreroften lasts from August to May, and undergo through five instars. Hatchlings often travel in a group to bore an entrance hole (approx. 0.5 x 1cm) at an internode of the bamboo (young shoots) in one day. The larvae live and feed on the fresh inner pulp of the bamboo, boring their way upwards from one bamboo internode to another. At this time, the bamboo is marked with signs of irregular growth patterns, shortened, uneven, and hard bark internodes. The bamboo gradually turn brown.

Thebamboo borer's infestation does not harm the bamboo, but instead makes the bamboo stronger than uninfected bamboo because of high density of small wooden cells. After 45 to 60 days, the larvae mature and migrate down to the internode containing the exit hole where they enter a period of diapause until May of next year. At there, they make a silk-web either on the top or in the middle of the internode and stay under or above the web. When migrating down, at each internode entrance, the larvae always make silk-web that seals the hole to prevent rain and natural predator. The path between the internodes is very small, rounded with a diameter of about 1 cm.

Of 35 sampled bamboo trees, bamboo borer bored their way from 12 to 22 internodes/tree but mostly from 12 to 19 internodes. Number of trees increased when number of bored internodes per tree increase from 12 to 14. However, when the number of bored internodes per tree kept increasing from 14 to 22, the number of tree decreased. Trees with 14 bored internodes made by bamboo borer were counted with the largest number, eight of 35 sampled trees (22.9%). The number of bored internodes depending on the density of larvae inside the tree. The larger number of larvae, the more food and internodes are needed and vice versa.

3.2.2.2. Biological feature of pupa stage

From May – June, the larvae enter the pupal stage. Pupae often hang upside down inside the internode. The pupal stage often lasts from 46-60 days. The metamorphosis from larva to pupa is as follows: At the 5th instar, the larvae of bamboo borerenter a period of diapause, then transition to the pre-pupal stage. At this stage, the larvae stopped eating, then turn their heads upside down to enter the pupation stage. The pupae are hung one fixed-bed by a spine at the bottom of the abdomen, the head pointing downwards. The fixed-bed is formed by silk threads interweaving together, shaped like a bird nest. Silk is produced from the spine at the bottom of the abdomen. Based on the hanging method, bamboo borer's pupa is called an upside-down pupa.

The color of pupa changes over time as it matures. When it is freshly developed, pupae have white-breasted abdomen, light green head, thorax, and wings. After a few hours, the entire body turns reddish brown (Figure 3.14). Therefore, observation of the pupal colour would give an indicator of the time they are about to emerge. This has implications for later breeding.

3.2.2.3. Biological feature of adult stage and egg

Adult stage takes place in July. Several hours after emergence, the adult finds a mate to copulate, and this process takes place at night. After which the female lays a cluster of about 80-130 eggs near the base of a bamboo shoot. The process of laying eggs is not consistent/continuous, could take up to2 - 6 days. The ova development takes place around 12 days, and adults live about 8 days.

3.2.2.4. Life cycle worksheet of bamboo borer

The bamboo borer has only one lifecycle per year and their life cycle lasts around 12 months. Life cycle's start and end as well as the occurrence time of stages during the year may change depend on yearly climate and weather conditions. Adults often appear in July. They lay eggs from the middle to the end of August. The larval period lasts from the end of August to early of May. A larva metamorphoses into a pupa at the end of May to early June. The larvae then undergo a period of diapause, which lasts from the end of October to May. Through field survey and information collected during interview survey, besides being exploited as food, bamboo borer are also confronted with many natural predator such as woodpeckers and some worm-eating ants though they are covered in trunk.

3.2.2.5. Distribution characteristics of bamboo borer in the Northwest region

In Vietnam, in general, in the northwestern region in particular, bamboo borerhas been found common in bamboo species such as: *Dendrocalamus membranaceus*; *Dendrocalamus hamiltonii* and *Dendrocalamus aff. Pachystachys*. On different host plant, bamboo borer infestation rate on clumps, on trees differs. Of these, *Dendrocalamus membranaceus* has the highest value (61% of the clump and 2.4% of the trees are infested, and 0.94 trees has Caterpillar per clump). This value gradually decreases from *Dendrocalamus hamiltonii* to *Dendrocalamus aff.*

Pachystachys. The highest number of tree has Caterpillar per clump was found in *Dendrocalamus membranaceus* (0.94 trees/clump) and lowest in *Dendrocalamus aff. Pachystachys* (0.44 trees/ clump) and in *Dendrocalamus hamiltonii* was 0.62 trees/clump. The density of Caterpillar inside the tree does not depend on the species, but the size of the bamboo trees.

3.2.3. Nutritional value of bamboo borer

3.2.3.1. Chemical composition of larval bamboo borer

The larvae are rich in nutrition, containing 11.26 grams Protein and 23.82 g Lipid per 100 g of Bamboo borer. Besides, it is good in minerals, especially kalium (331.50 mg/100g), magnesium (212.64 mg/100g), calcium (107.26 mg/100g) and zinc (4.14 mg/100g).

3.2.3.2. Composition and content of amino acids of bamboo borer's larva

The total amino acid content of Bamboo borer is 473.44 mg/100g. It can be confirmed that seventeen amino acids of twenty amino acids are found in bamboo borer. Of these, the bamboo bore protein produces seven per eight essential amino acids for human (no Tryptophan) including: Isoleucine (7.16 mg/100g), Leucine (15.46 mg/100g), Lysine (14.57 mg/100g), Methionine (0.86 mg/100g), Phenylalanine (12.98 mg/100g), Treonine (17.43 mg/100g) and Valine (2.96 mg/100g). Bamboo bore also has Histidine (118.0 mg/100g) and Arginine (11.36 mg/100g), two essential amino acids for children and some others amino acids like Aspartic acid (86,27 mg/100g), Serine (14,97 mg/100g), Glutamic acid (55,67 mg/100g), Glycin (20,85 mg/100g), Alanin (10,33 mg/100g), Prolin (54,0 mg/100g), Cystin (5,41 mg/100g) and Tyrosin (25,16 mg/100g).

3.2.3.3. Composition and content of fatty acids of bamboo borer's larvae

The total lipid content in 100 grams of fresh bamboo bore larva is 23.82g. There are twenty two fatty acids found in the larva, of which 10 saturated fatty acids (9.87 g/100g) and twelve un-saturated fatty acids (9.44 g/100g). Bamboo bore's larvae also contains 0.312g/100g of Linoleic Acid (Omega 6 fatty acids) and 0.065g/100g of Linolenic Acid (Omega 3 fatty acids) are the two most important types of essential fatty acids (EFAs). These acds have the highest nutritional value and is considered as vitamins (vitamin F) that the body can not make itself, so it must be supplemented from the outside.

3.3. Proposing solutions to conserve valuable edible insects in the Northwest region.

3.3.1. Proposing the management and conservation solutions of edible insects

3.3.1.1. Social-economic development solutions: Forestry land planning is needed. Conversion of slash-and-burn abandoned agricultural land to plantation forest, agroforestry, separated pasture planning... Strengthening of international cooperation and support, implementing of in situ conservation programs for species of edible insects. Local people must be involved as stakeholders in the planning and management of forest resources if it affects to their livelihoods.

3.3.1.2. Communication and education solutions: Informing to the local people about the forest insects with valuable food in the Northwest region and forest insects must be recognized as forest resources.

3.3.1.3. Sustainable exploitation solutions: When exploiting edible insects should not be overexploited, exhausted exploitation. When collecting honey, should only use smoke to flee the adult bees away, do not use fire to burn. After honey exploitation, needs to rearrange the wax layers to facilitate the reproduction of the bees. Particularly, do not kill young bees and mature bees, set a limitation of taking bee's larvae for food.

3.3.1.4. Breeding solution: Selectingseveral insect species of high economic value to research and develop experiment breeding models. It is necessary to carry out study on breeding more other potential species. According to research results, bamboo borer (*Omphisafucidentalis*) is one of the species that needs to be focused on development in the future to contribute to economic development, poverty reduction and forest protection.

3.3.2. Proposing the management and conservation solutions for specific valuable edible insects groups

3.3.2.1. Management solutions for natural predatorand specialty insects

Groups of natural predator and specialty insects need to be protected and developed. Apart from propaganda, their food sources and habitats also need appropriate silvicultural measures. In order to effectively implement the protection, firstly it is necessary to identify these species. Implementing propaganda with pictures, photos and leaflets are appropriate measures for people to easily identify these species and participate in the protection.

3.3.2.2. Solution for precious, rare insect species: Lethocerus indicus is a special species (listed in the Red Book of Vietnam in 1992, 2000, 2007), needs to be protected and developed. In addition to propaganda, it is important to protect the habitat and food supply of this insect. It is also necessary to minimize the use of pesticides and chemical fertilizers for preventing pests and diseases and use organic fertilizers in agro-forestry to avoid water pollution that will be affected the development and existence of aquatic ecosystem in general and *Lethocerus indicus*in particular.

3.3.2.3. Pest insect management solution: When pests appear, collect them for food. For each insect species, appropriate harvesting methods are needed to achieve high efficiency and safety without impacting the biodiversity.

3.3.3. Proposing specific management solution for bamboo borer

It is necessary to have certain knowledge about bamboo borer such as: morphology, biology and ecology; It is necessary to breed and expand the area of 3 species of Bamboo as *Dendrocalamus membranaceus*; *Dendrocalamus hamiltonii* and *Dendrocalamus aff. Pachystachys* which are home for bamboo borer; it is also necessary to implement research on techniques of breeding bamboo borer at industrial scale and technology transfer for local people. In addition, it is necessary to propagate and develop bamboo borer as an attractive source of income for local people and contribute to forest protection.

CONCLUSION & RECOMMENDATION

A. CONCLUSION

- List of edible insect species in the Northwest region: 34 species, 31 genus and 21 families of 9 insect orders were recorded. Of these, 10 species are common in many forest habitats, 9 species distribute in agricultural habitats, 3 species in aquatic habitats, and the other species in many agro-forestry habitats. There are 5 dominant orders of insects, (8 species of Hymenoptera, 7 species of

Orthoptera, 5 species of Coleoptera, 4 species of Lepidoptera and Hemiptera) accounting for 82.4% of the edible insect species in the Northwest. Insects are used as food in most growth stages, larva stage (28/34 species), pupa to adult stage (25/34 species) and for commercial products (8.8%). Systematizing and providing some indigenous knowledge of local people for exploitation of edible insects in terms of capture, pre-processing, processing into food from forest insects.

- Presenting some data on the morphology and biology of bamboo borer in the study area: Pupae and larvae live inside bamboo stem. Larvae have 13 segments, a mandibulatory mouth part, mouth tip down; The larva stage has five instars. In the first instar, larvae bore an entrance holeat an internode of the bamboo (young shoots). The larval stageoften takes place between 40 to 60 days. The female lays a cluster of about 80-130 eggs near the base of a bamboo shoot. The ova development takes place around 12 days and adults live about 8 days. The bamboo borer has only one lifecycle per year. Adults often appear in July, they lay eggs from early to middle of August. The larval period lasts from the end of August to next May. A larva metamorphoses into a pupa at the middle of May to end of June. The pupa then undergo a period of diapause, which lasts from the end of October to the beginning of next May.

- Identification of biochemical ingredients and nutritional values of bamboo borer in the Northwest region, Vietnam: Protein (11.26 g/100g), Lipid (23.82 g/100g) and minerals. There are 17/20 types of amino acids in bamboo borer, including 7/8 essential amino acids for human body (without Tryptophan). Bamboo borer also have Histidin and Arginine, essential amino acids for children. There are 22 fatty acids in Bamboo borer in which 10 saturated fatty acids (9.87 g/100g, mainly Palmitic for 95.8%) and 12 un-saturated fatty acids (9.44 g/100g, mainly Oleic for 80.7%). In addition, Bamboo borer also contains linoleic acid and linolenic acid.

- Proposed 5 groups of solutions for managing and conservasing edible insects: (1) Socio-economic development solutions; (2) Solutions on communication and education; (3) Sustainable exploitation solution; (4)

Breeding solution; (5) Proposing the management and conservation solutions for each group of edible insects: for pest insects group, promoting the usage of them as food; for natural predators, specialties or conservation value group, in addition to use as food, need to take measures to protect and develop.

- Proposed specific management solution for bamboo borer: There should be basic information about bamboo borer; Plant host plants of bamboo borer; Breeding bamboo borer at industrial scale and transfer technology to the people.

B. RECOMMENDATION

Continue to collect additional information on the food insect species in the Northwest of Vietnam.

It is necessary to develop a plan for the conservation and development of rare and endangered insects, such as *Lethocerus indicus*and other useful insects such as: green mantis, ants, and bees. .

Invest in the development of insect rearingjobs in general and bamboo borer in particular with a comprehensive technological system to help people develop sustainable social and economy.